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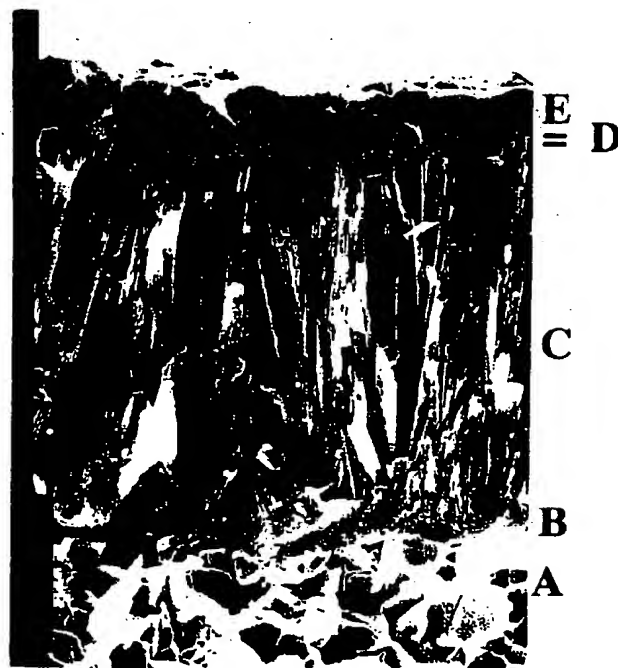
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(54) **Coated cutting insert**

(57) The present invention discloses a coated cutting insert particularly useful for intermittent cutting in low alloyed steel. The insert is characterised by a WC-

Co-based cemented carbide body having a highly W-alloyed Co-binder phase and a coating including an innermost layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with columnar grains and a top coating of a fine grained, textured  $\alpha\text{-Al}_2\text{O}_3$ -layer.



**Fig. 1**

## Description

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for intermittent cutting in low alloyed steel.

Low alloyed steel is a material which, in general, is difficult to machine with coated or uncoated cemented carbide tools. Smearing of workpiece material onto the cutting edge and flaking of the coating often occur. The cutting condition is particularly difficult when intermittent machining is employed under wet conditions (using coolant).

When machining low alloyed steels by coated cemented carbide tools the cutting edge is worn by chemical wear, abrasive wear and by a so called adhesive wear. The adhesive wear is often the tool life limiting wear. Adhesive wear occurs when fragments or individual grains of the layers and later also parts of the cemented carbide are successively pulled away from the cutting edge by the workpiece chip formed. Further when wet cutting is employed the wear may also be accelerated by an additional wear mechanism. Coolant and workpiece material may penetrate into the cooling cracks of the coatings. This penetration often leads to a chemical reaction between workpiece material and coolant with the cemented carbide. The Co-binder phase may oxidise in a zone near the crack and along the interface between the coating and the cemented carbide. After some time coating fragments are lost piece by piece. It has surprisingly been found that by combining the following features: a cemented carbide body with a highly W-alloyed binder phase, a columnar  $\text{TiC}_x\text{N}_y\text{O}_z$ -layer, a textured  $\alpha\text{-Al}_2\text{O}_3$ -layer, a treatment of the coating surface by wet-blasting or by brushing an excellent cutting tool for low alloyed steel cutting can be obtained.

Fig 1 is a micrograph in 5000X magnification of a coated insert according to the present invention in which

- A - cemented carbide body
- B -  $\text{TiC}_x\text{N}_y\text{O}_z$ -layer with equiaxed grains
- C -  $\text{TiC}_x\text{N}_y\text{O}_z$ -layer with columnar grains
- D -  $\text{TiC}_x\text{N}_y\text{O}_z$ -layer with equiaxed or needle like grains
- E - textured  $\alpha\text{-Al}_2\text{O}_3$ -layer with columnar like grains

According to the present invention a cutting tool insert is provided with a cemented carbide body of a composition 5 - 11 wt-% Co, preferably 5 - 8 wt-% Co, <10 wt-%, preferably 1.5 - 7.5 wt-%, cubic carbides of the metals Ti, Ta and/or Nb and balance WC. The grain size of the WC is 1 - 3  $\mu\text{m}$ , preferably about 2  $\mu\text{m}$ . The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the

$$\text{CW-ratio} = M_s / (\text{wt-\% Co} \cdot 0.0161),$$

where  $M_s$  is the measured saturation magnetization of the cemented carbide body and wt-% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A low CW-value corresponds to a high W-content in the binder phase.

It has now been found according to the invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.76 - 0.93, preferably 0.80 - 0.90. The cemented carbide body may contain small amounts, <1 volume-%, of eta phase ( $\text{M}_6\text{C}$ ), without any detrimental effect. In a preferred embodiment a thin (about 15 - 35  $\mu\text{m}$ ) surface zone depleted of cubic carbides and often enriched in binder phase can be present according to prior art such as disclosed in US 4,610,931. In this case the cemented carbide may contain carbonitride or even nitride.

The coating comprises

- a first (innermost) layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with  $x+y+z=1$ , preferably  $z<0.5$ , with a thickness of 0.1 - 2  $\mu\text{m}$ , and with equiaxed grains with size <0.5  $\mu\text{m}$
- a second layer of  $\text{TiC}_x\text{N}_y\text{O}_z$   $x+y+z=1$ , preferably with  $z=0$  and  $x>0.3$  and  $y>0.3$ , with a thickness of 2 - 15  $\mu\text{m}$ , preferably 5 - 8  $\mu\text{m}$ , with columnar grains and with a diameter of about <5  $\mu\text{m}$ , preferably <2  $\mu\text{m}$
- a third layer of  $\text{TiC}_x\text{N}_y\text{O}_z$ ,  $x+y+z=1$  with  $z\leq 0.5$ , preferably  $z>0.1$ , with a thickness of 0.1 - 2  $\mu\text{m}$  and with equiaxed or needle like grains with size <0.5  $\mu\text{m}$ , this layer being the same as or different from the innermost layer
- a fourth layer of a smooth, textured, fine-grained (grain size about 0.5 - 2  $\mu\text{m}$ )  $\alpha\text{-Al}_2\text{O}_3$ -layer with a thickness of 2 - 10  $\mu\text{m}$ , preferably 3 - 6  $\mu\text{m}$ , and a surface roughness  $R_{\text{max}}\leq 0.4 \mu\text{m}$  over a length of 10  $\mu\text{m}$ . Preferably, this  $\text{Al}_2\text{O}_3$ -layer is the outermost layer but it may also be followed by further layers such as a thin (about 0.1 - 1  $\mu\text{m}$ ) decorative layer of e.g TiN.

In addition, the  $\alpha\text{-Al}_2\text{O}_3$ -layer has a preferred crystal growth orientation in either the (104)-, (012)- or (110)-direction, preferably in the (012)-direction, as determined by X-ray Diffraction (XRD) measurements. A Texture Coefficient, TC,

can be defined as:

$$TC(hkl) = \frac{I(hkl)}{I_o(hkl)} \left\{ \frac{1}{n} \sum \frac{I(hkl)}{I_o(hkl)} \right\}^{-1}$$

where

$I(hkl)$  = measured intensity of the  $(hkl)$  reflection

$I_o(hkl)$  = standard intensity of the ASTM standard powder pattern diffraction data

$n$  = number of reflections used in the calculation,  $(hkl)$  reflections used are: (012), (104), (110), (113), (024), (116)

According to the invention TC for the set of (012), (104) or (110) crystal planes is larger than 1.3, preferably larger than 1.5.

According to method of the invention a WC-Co-based cemented carbide body having a highly W-alloyed binder phase with a CW-ratio according to above is coated with

- a first (innermost) layer of  $TiC_xN_yO_z$  with  $x+y+z=1$ , preferably  $z<0.5$ , with a thickness of 0.1 - 2  $\mu m$ , and with equiaxed grains with size  $<0.5 \mu m$  using known CVD-methods.
- a second layer of  $TiC_xN_yO_z$   $x+y+z=1$ , preferably with  $z=0$  and  $x>0.3$  and  $y>0.3$ , with a thickness of 2 - 15  $\mu m$ , preferably 5 - 8  $\mu m$ , with columnar grains and with a diameter of about  $<5 \mu m$ , preferably  $<2 \mu m$ , deposited preferably by MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700 - 900 °C). The exact conditions, however, depend to a certain extent on the design of the equipment used.
- a third layer of  $TiC_xN_yO_z$ ,  $x+y+z=1$  with  $z\leq 0.5$ , preferably  $z>0.1$ , with a thickness of 0.1 - 2  $\mu m$  and with equiaxed or needle like grains with size  $\leq 0.5 \mu m$ , using known CVD-methods this layer being the same as or different from the innermost layer.
- a fourth (outer) layer of a smooth, textured  $\alpha-Al_2O_3$ -layer according to Swedish patent 501 527 or Swedish patent applications 9304283-6 or 9400089-0 with a thickness of 2 - 10  $\mu m$ , preferably 3 - 6  $\mu m$ , and a surface roughness  $R_{max}\leq 0.4 \mu m$  over a length of 10  $\mu m$ . The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with fine grained (400 - 150 mesh) alumina powder or by brushing the edges with brushes based on e.g SiC as been disclosed in the Swedish patent application 9402543-4.

When a  $TiC_xN_yO_z$ -layer with  $z>0$  is desired,  $CO_2$  and/or  $CO$  are/is added to the reaction gas mixture.

#### Example 1.

A. Cemented carbide cutting tool inserts of style CNMG 120408-SM with the composition 7.5 wt-% Co, 1.8 wt-% TiC, 0.5 wt-% TiN, 3.0 wt-% TaC, 0.4 wt-% NbC and balance WC with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.88 were coated with a 0.5  $\mu m$  equiaxed TiCN-layer followed by a 7  $\mu m$  thick TiCN-layer with columnar grains by using MTCVD-technique (process temperature 850 °C and  $CH_3CN$  as the carbon/nitrogen source). In subsequent process steps during the same coating cycle, a 1  $\mu m$  thick layer of  $TiC_xN_yO_z$  (about  $x=0.6$ ,  $y=0.2$  and  $z=0.2$ ) with equiaxed grains was deposited followed by a 4  $\mu m$  thick layer of (012)-textured  $\alpha-Al_2O_3$  deposited according to conditions given in Swedish patent 501 527. XRD-measurement showed a texture coefficient TC(012) of 1.6 for the  $\alpha-Al_2O_3$ -layer. The cemented carbide body had a surface zone about 25  $\mu m$  thick, depleted from cubic carbides.

B. Cemented carbide cutting tool inserts of style CNMG 120408-SM from the same batch as in A.) were coated with a 0.5  $\mu m$  equiaxed TiCN-layer followed by a 7  $\mu m$  thick TiCN-layer with columnar grains by using MTCVD-technique (process temperature 850 °C and  $CH_3CN$  as the carbon/nitrogen source). In subsequent process steps during the same coating cycle, a 1  $\mu m$  thick layer of  $TiC_xN_yO_z$  (about  $x=0.6$ ,  $y=0.2$  and  $z=0.2$ ) with equiaxed grains was deposited followed by a 4  $\mu m$  thick layer of (104)-textured  $\alpha-Al_2O_3$  deposited according to conditions given in Swedish patent application 9400089-0. XRD-measurement showed a texture coefficient TC(104) of 1.7 for the  $\alpha-Al_2O_3$ -layer.

C. Cemented carbide cutting tool inserts of style CNMG 120408-SM with the composition 6.5 wt-% Co and 8.8 wt-% cubic carbides (3.3 wt-% TiC, 3.4 wt-% TaC and 2.1 wt-% NbC) and balance WC were coated under the procedure given in A). The cemented carbide body had a CW-ratio of 1.0. XRD-measurement showed a texture coefficient TC(012) of 1.5 for the  $\alpha-Al_2O_3$ -layer.

D. Cemented carbide cutting tool inserts of style CNMG120408-SM from the same batch as in A.) were coated

with a 6 µm equiaxed layer of TiCN followed by a 4 µm thick layer of Al<sub>2</sub>O<sub>3</sub>-layer according to prior art technique. XRD-analysis showed that the Al<sub>2</sub>O<sub>3</sub>-layer consisted of a mixture of α and κ-Al<sub>2</sub>O<sub>3</sub>, approximately in the ratio 30/70.

E. Cemented carbide cutting tool inserts from the same batch as in C) were coated according to the procedure given in D.). XRD-analysis showed that the Al<sub>2</sub>O<sub>3</sub>-layer consisted of a mixture of α and κ-Al<sub>2</sub>O<sub>3</sub> in a ratio of about 20/80.

Before performing the cutting tests all inserts from A.)-E.) were wet blasted using an alumina-water slurry in order to smooth the coating surfaces.

The inserts were tested in an intermittent longitudinal turning operation. The workpiece material was a low alloyed low carbon steel (SCr420H) in the shape of a 22 mm thick ring with an outer diameter of 190 mm and an inner diameter of 30 mm. Each longitudinal passage over the ring thickness consisted of 22 in-cuts of one mm each. The number of passages over the ring thickness until flaking occurred was recorded for each variant.

| Variant |   | Number of passages before edge flaking |
|---------|---|--|
| A.)     | according to the invention highly W-alloyed cemented carbide body columnar coating/012-α-Al <sub>2</sub> O <sub>3</sub> | 165                                    |
| B.)     | according to the invention highly W-alloyed cemented carbide body columnar coating/104-α-Al <sub>2</sub> O <sub>3</sub> | 117                                    |
| C.)     | low W-alloyed cemented carbide body columnar coating/012-α-Al <sub>2</sub> O <sub>3</sub> (comparative)                 | 60                                     |
| D.)     | highly W-alloyed cemented carbide body equiaxed coating/α+κ-Al <sub>2</sub> O <sub>3</sub> (comparative)                | 15                                     |
| E.)     | low W-alloyed cemented carbide body equiaxed coating/α+κ-Al <sub>2</sub> O <sub>3</sub> (comparative)                   | 15                                     |

#### Example 2

F. Cemented carbide cutting tool inserts of style CNMG 120408-QM with the composition 7.5 wt-% Co, 2.3 wt-% TiC, 3.0 wt-% TaC, 0.4 wt-% NbC and balance WC and a binder phase highly alloyed with W corresponding to a CW-ratio of 0.83 were coated with a 0.5 µm equiaxed TiCN-layer followed by a 7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (process temperature 850 °C and CH<sub>3</sub>CN as the carbon/nitrogen source). In subsequent process steps during the same coating cycle, a 1 µm thick layer with equiaxed grains of TiC<sub>x</sub>N<sub>y</sub>O<sub>z</sub> (about x=0.6, y=0.2 and z=0.2) was deposited followed by a 4 µm thick layer of (012)-textured α-Al<sub>2</sub>O<sub>3</sub> deposited according to conditions given in Swedish patent 501 527. The cemented carbide body did not have any depleted zone of cubic carbides near the surface (as the inserts had in Example 1, A.).

XRD-measurement showed a texture coefficient TC(012) of 1.5 of the α-Al<sub>2</sub>O<sub>3</sub>-layer.

G. Cemented carbide cutting tool inserts in style CNMG12040-QM with the composition 5.5 wt-% Co and 8.4 wt-% cubic carbides (2.6 wt-% TiC, 3.5 wt-% TaC and 2.3 wt-% NbC) and balance WC were coated according to the procedure given in D.). The cemented carbide body had a CW-ratio of 0.98.

XRD-analysis showed that the Al<sub>2</sub>O<sub>3</sub>-layer consisted of a mixture of α and κ-Al<sub>2</sub>O<sub>3</sub> in approximate ratio of 25/75

H. Cemented carbide cutting tool inserts from the same batch as in G.) were coated under the procedure given in A) XRD-measurement showed a texture coefficient TC(012) of 1.6.

All insert F.)-G.) were brushed in order to smooth the coating surface along the cutting edge and tested according to the method given in example 1.

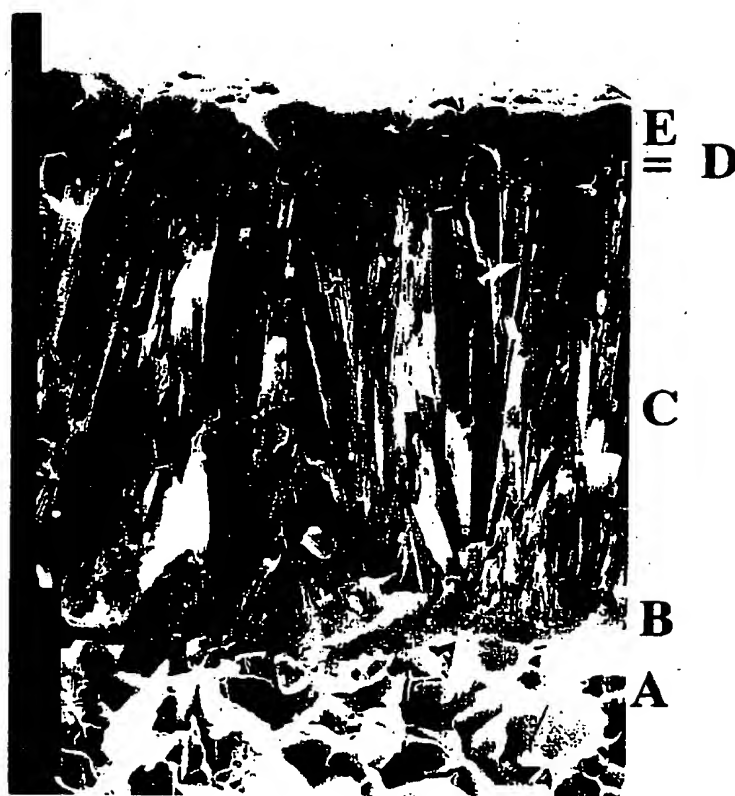
| Variant |   | Number of passages before edge flaking |
|---------|---|--|
| F.)     | according to the invention highly W-alloyed cemented carbide body columnar coating/012-α-Al <sub>2</sub> O <sub>3</sub> | 150                                    |
| G.)     | highly W-alloyed cemented carbide body equiaxed coating/α+κ-Al <sub>2</sub> O <sub>3</sub> (comparative)                | 15                                     |
| H.)     | low W-alloyed cemented carbide body columnar coating/012-α-Al <sub>2</sub> O <sub>3</sub> (comparative)                 | 60                                     |

#### Claims

1. A cutting tool insert for machining of low alloyed steel comprising a cemented carbide body and a coating char-

**acterised** in that said cemented carbide body consists of WC, 5 - 11 wt-% Co and 0 - 10 wt-% cubic carbides of metals from groups IVb, Vb or VIb of the periodic table and a highly W-alloyed binder phase with a CW-ratio of 0.76 - 0.93 and in that said coating comprises

- 5
  - a first (innermost) layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 0.1 - 2  $\mu\text{m}$ , and with equiaxed grains with size  $<0.5 \mu\text{m}$
  - a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 2-15  $\mu\text{m}$  with columnar grains with a diameter of about  $<5 \mu\text{m}$
  - a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 0.1 - 2  $\mu\text{m}$  and with equiaxed or needle like grains with size  $\leq 0.5 \mu\text{m}$
  - an outer layer of a smooth, textured, fine-grained (0.5 - 2  $\mu\text{m}$ )  $\alpha\text{-Al}_2\text{O}_3$ -layer with a thickness of 2 - 10  $\mu\text{m}$
- 10 2. Cutting insert according to the preceding claim **characterised** in that the  $\alpha\text{-Al}_2\text{O}_3$ -layer has a texture in (012)-direction and with a texture coefficient TC(012) larger than 1.3.
3. Cutting insert according to claim 1 **characterised** in that the  $\alpha\text{-Al}_2\text{O}_3$ -layer has a texture in the (104)-direction and with a texture coefficient TC(104) larger than 1.3.
- 15 4. Cutting insert according to claim 1 **characterised** in that the  $\alpha\text{-Al}_2\text{O}_3$ -layer has a texture in (110)-direction and with a texture coefficient TC(110) larger than 1.3.
- 20 5. Cutting insert according to the preceding claims **characterised** in an outermost coating of a thin 0.1 - 1  $\mu\text{m}$  TiN-layer.
6. Method of making a cutting insert comprising a cemented carbide body and a coating **characterised** in that WC-Co-based cemented carbide body is coated with
  - 25 - a first (innermost) layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 0.1 - 2  $\mu\text{m}$ , with equiaxed grains with size  $<0.5 \mu\text{m}$  using known CVD-methods
  - a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 2 - 15  $\mu\text{m}$  with columnar grains and with a diameter of about  $<5 \mu\text{m}$  deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850 - 900 °C.
  - 30 - a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with a thickness of 0.1-2  $\mu\text{m}$  with equiaxed or needle like grains with size  $\leq 0.5 \mu\text{m}$ , using known CVD-methods
  - an outer layer of a smooth textured  $\alpha\text{-Al}_2\text{O}_3$ -layer textured in the direction (012), (104) or (110) with a thickness of 2 - 10  $\mu\text{m}$ .



**Fig. 1**

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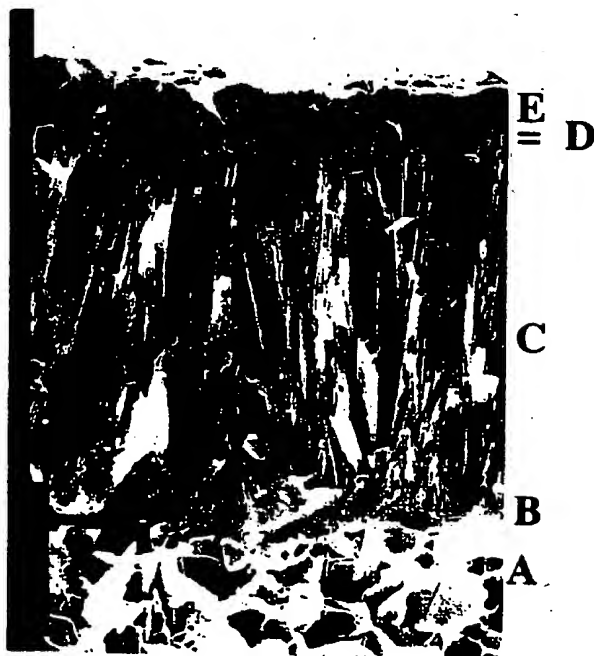
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**Fig. 1**

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# EUROPEAN SEARCH REPORT

Application Number  
EP 96 85 0129

| DOCUMENTS CONSIDERED TO BE RELEVANT   |  |  |   |
|---|--|--|---|
| Category  | Citation of document with indication, where appropriate, of relevant passages              | Relevant to claim  | CLASSIFICATION OF THE APPLICATION (Int.Cl.6)            |
| E   | EP 0 736 615 A (SANDVIK AB) 9 October 1996<br>* claims 1-6 *                               | 1-6  | C23C28/04<br>C23C16/30<br>C23C16/40<br>B23B27/14        |
| P,X   | EP 0 709 484 A (MITSUBISHI MATERIALS CORP)<br>1 May 1996<br>* claims 1-9; table 5 *        | 1-6  |   |
| P,X   | EP 0 685 572 A (MITSUBISHI MATERIALS CORP)<br>6 December 1995<br>* claims 1-12; figure 1 * | 1-6  |   |
| X   | EP 0 600 115 A (MITSUBISHI MATERIALS CORP)<br>8 June 1994<br>* claims 1-11; table 2 *      | 1-6  |   |
| The present search report has been drawn up for all claims  |  |  | <b>TECHNICAL FIELDS SEARCHED (Int.Cl.6)</b><br><br>C23C |
| Place of search<br><b>THE HAGUE</b>   |  | Date of completion of the search<br><b>19 March 1997</b> | Examiner<br><b>Gregg, N</b>                             |
| <b>CATEGORY OF CITED DOCUMENTS</b><br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>I : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |  |  |   |

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